Phys.526 Statistical Physics--Spring 2013

Class Hours:10:00-10:50AM MWF; Class Room: MEL 251

Instructor: Huey W. Huang

Office Hours: MTu 2-5 or by appointment at Rm 252 Brockman Hall

Email: hwhuang@rice.edu with subject: Phys526

Website: www.ruf.rice.edu/~hwhuang/Phys526.pdf

Textbook: Equilibrium and Non-Equilibrium Statistical Thermodynamics
by M. Le Bellac, F. Mortessagne, and G. G. Batrouni
(Cambridge University Press, 2004; ISBN 0-521-82143-6)

This course extends the undergraduate thermal physics to a more advanced level so as to prepare the graduate students for the research literature on the subjects of modern statistical physics. Students who take Phys. 526 should already understand thermodynamics and the Maxwellian kinetic theory of gases. We will use the textbook "Equilibrium and Non-Equilibrium Statistical Thermodynamics" by Le Bellac, Mortessagne, and Batrouni. We will cover topics related to the first five chapters, namely, the equilibrium statistical mechanics, including the introductory-level renormalization group theory, quantum Hall effect, and quantum phase transitions. The remaining chapters that we will have no time to cover include excellent introductions to the following subjects: Chapter 6, derivations to hydrodynamic equations, dynamics in the long-wavelength/low-frequency limits. Chapter 7, an introduction to the methods of numerical simulations. Chapter 8, the Boltzmann transport equation. Chapter 9, the linear response theory.

One reason for choosing this textbook is that it contains a large number of exercises and problems. There is no better way of testing your comprehension by trying out these problems. I will assign homework on the website www.ruf.rice.edu/~hwhuang/HW526.pdf at least a week ahead of the due time. One set of homework will be due every Wednesday (unless specified otherwise). You are asked to turn in your homework at the beginning of the Wednesday class. We will then discuss the homework solutions—no printed solutions will be distributed. Unless you have a legitimate excuse, late homework is not acceptable.

It is impossible to overemphasize the importance of homework. You learn the most from doing the problems yourself, including making and correcting mistakes. You are allowed to discuss homework with fellow students and with me, but ONLY after you have tried the problems yourself. Note: the first step of the solution is usually the key; the rest is usually straightforward. If you habitually rely on others to give you the first step, you probably have not learned the subject.

The course grade will be determined by the homework (70%) and a final (30%).

* Any student with a documented disability needing academic adjustments or accommodations is requested to speak with me during the first two weeks of class. All discussions will remain confidential. Students with disabilities should also contact Disability Support Services in the Ley Student Center.

Physics 526 Statistical Physics

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CONTENT (additional topics are discussed in homework every Wednesday)

1. Principles of Thermodynamics and Statistical Mechanics (Read Chaps 1-3)
   - 1.1 Entropy Maximum Principle S(E,V,N)
     Internal variables, Equilibrium conditions, Concavity of entropy
   - 1.2 Energy Minimum Principle E(S,V,N)
     $E = TdS - PdV - \mu dN$, Euler relation, Gibbs-Duhem relation, Stability conditions
   - 1.3 Free Energy Minimum Principles
     Legendre transformation, Susceptibilities, Maxwell relations, Differentials (math)
   - 1.4 Principle of Statistical Mechanics
     Quantum phase space, Boltzmann's definition of entropy, Microcanonical ensemble
   - 1.5 Canonical Ensemble and Grand Canonical Ensemble
     Partition functions, First derivatives, Second derivatives, Correlation functions
   - 1.7 Simple examples
     Density of states.
     Ideal gases, Quantum gases versus classical gases
     Interacting systems, Magnetism, Heisenberg's exchange interaction, 1D Ising model

2. Quantum Gases (Read Chap 5)
   - 2.1 Electron gas
     Classical limit, Low temperature limit
   - 2.2 Electron gas in magnetic field
     Bohr-van Leeuwen's theorem, Landau diamagnetism, Quantum Hall effect
   - 2.3 Boson gases
     - 2.3.1 Black-body radiation,
       Thermodynamic consideration, discovery of quantum theory, cosmic radiation
     - 2.3.2 Debye theory of phonons
     - 2.3.3 Bose-Einstein condensation

3. Phase Transitions and Critical Phenomena (Read Chap 4)
   - 3.1 $F = E - TS$; Order-disorder phase transitions
     First-order phase transition: Maxwell construction, Phase equilibrium, Gibbs' phase rules, Clapeyron-Clausius relation
     Theorems for existence or non-existence of certain ordered phases
   - 3.2 Mean Field Theory
     - 3.2.1 Bragg-William approximation, Weiss approximation
     - 3.2.2 Landau Theory, order parameter, broken symmetry, correlation functions, critical exponents, universality
   - 3.3 Scaling Hypothesis
     Homogeneous functions, Widom's scaling laws, Kadanoff's spin block renormalization
   - 3.4 Renormalization group theory

1D Ising model
Gaussian model
Wilson’s k-space renormalization
3.5 Quantum phase transition
Quantum Ising chain in a transverse field